PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

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QUARTERLY 2006 No. 2

Light Armor Vehicle Off to War

For the past three years, ARL Penn State was fortunate to have a Light Armor Vehicle (LAV-25) on loan from the Marine Corps. Custody of the vehicle facilitated the addressing of several vehicle issues. Unfortunately, the vehicle was recently recalled and returned to Marine Corps Logistics Base Albany (GA) for refurbishment. Following those efforts, the vehicle will likely see service in Iraq.

During the LAV's time aboard ARL, several ARL departments (to include iMAST) took advantage of the opportunity to initiate technical efforts which we believe will enhance not only this vehicle, but new combat vehicles to come. Initially, ballistic tolerance tests were conducted to evaluate the quality of previous repair welds performed on the vehicle. The evaluation was conducted to determine if any of the strength of the vehicle had been compromised as a result of repairs completed in the field. Following this evaluation, vehicle noise issues were addressed by ARL's Fluids ad Structural Mechanics office in an attempt to quantify noise signatures relative to an Infra-red (IR) signature-reducing muffler shroud replacement for the current design-of-record MEWSS PIP Light Armored Vehicle. The availability of this vehicle allowed real-time testing to be conducted. Sound pressure spectra was measured at a number of angular orientations relative to the stationary vehicle, with the baseline muffler and the IR signature-reducing shroud/muffler installed. Interior vehicle noise was also evaluated, with emphasis placed on identifying and correcting issues that would reduce dB levels detrimental to the vehicle's four-man crew. Concurrent with the noise reduction effort, the vehicle was instrumented relative to an ARL initiative addressing complex systems monitoring for furthering condition-based maintenance. Complex systems monitoring implements advanced diagnostic technologies for machinery health monitoring and supports basic and applied research in technologies related to diagnostics and prognostics for electro-mechanical systems. These systems include rotating components, weapons system platforms, and machinery networks. Proven analysis techniques, such as artificial intelligence, neural networks, and signal processing are integrated into the program effort.

There is a saying that all good things must come to an end. Although the LAV has been shipped back to the Marine Corps, ARL is fortunate to have received the loan of a Heavy Expanded Mobility Truck for further complex systems monitoring efforts. The vehicle supports ARL's growing Ground Combat/Combat Service Support Vehicle Technology group which was formed to integrate advanced materials, manufacturing processes, health monitoring and acoustic tailoring to reduce gross weight, vibration, interior noise, and life cycle costs, as well as increase mission range, survivability, and operational availability. The cost of these improvements are made more affordable due to large reductions in labor, as well as operating and support costs. For more information on this group, please contact Greg Johnson at (814) 865-8207 or by e-mail at <gjj1@psu.edu>.

Focus On Systems Operations and Automation

Report Documentation Page

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IN THIS QUARTERLY

DIRECTOR'S CORNER

Impacting Cost, Performance and Readiness

Fiscal Year 2006 is well over half way over. Exciting progress has been made on several fronts. The iMAST center has started two projects in support of the Littoral Combat Ship, supporting two of the three shipbuilders. RAdm William Landay has taken command of the Office of Naval Research. He has emphasized the need for the Manufacturing Technology Program to focus on improving the affordability of building ships. With the pressure of supporting the war in Iraq, plus the low volume nature of shipbuilding, costs for ships are higher than ever before. Add into the equation the desire for high performance and reduced manning, both have significant impact on the acquisition costs. While every program manager desires to reduce total ownership costs, "sticker shock" often forces decisions which will reduce acquisition costs, but add to total ownership costs.

The feature article this issue addresses Autonomic Logistics (AL). AL is great example of technology which will reduce total ownership costs. By increasing the availability of a vehicle, fewer vehicles will be necessary to complete missions, so fewer vehicles need to be purchased, fewer vehicles need to be shipped to the acquisition professionals while not adding significantly increasing acquisition costs.

In this issue you will notice a number of items addressing ground combat and combat service support vehicle technology efforts. This was not a coincidence. Penn State, ARL and iMAST have an extensive effort underway relative to ground vehicle technologies. We have both research and extensive test capabilities. If you are interested in finding out more about the various project efforts we have on-going, or want to find out more about our test and evaluation capabilities, please give me or my administrator (Greg Johnson) a call. If we can't address your issues specifically, we will direct you accordingly.

As we prepare for the next fiscal year, iMAST is exploring issues focused on reducing the shipbuilding costs of the major acquisition programs, the next generation aircraft carrier, the DDG 1000 (DDX), the VIRGINIA class submarine and the Littoral Combat Ship. There should be many opportunities. I encourage you to work with us to explore additional ideas.

Bob Cook

MATERIALS PROCESSING TECHNOLOGIES

MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES

LASER PROCESSING TECHNOLOGIES

COMPLEX SYSTEMS MONITORING TECHNOLOGIES

ADVANCED COMPOSITES MATERIALS TECHNOLOGIES

NAVY/MARINE CORPS REPAIR TECHNOLOGIES

MANUFACTURING SYSTEMS TECHNOLOGIES

Focus on Systems Operations and Automation

Embedded Diagnostic Technology as an Enabler of Autonomic Logistics for Military Ground Vehicles

by Jeffrey Banks

Military ground vehicles comprise a large part of the U.S. arsenal. They perform as weapons platforms, personnel carriers, and supply and support vehicles for a wide variety of mission profiles. High operational availability (Ao) of these vehicles is critical to achieving their mission objectives. This is accomplished by effective maintenance, supply and support enabled by a well integrated and effective global combat support system. When system status and platform health information is monitored on each vehicle and reported up through the echelons, then these processes can be most effectively executed, which results in high vehicle operational availability.

It has been identified that the key to future Marine Corps war fighting concepts is Distributed Operations (DO) [Distributed Operations Maneuver Warfare, http://www.mcwl.usmc.mil/SV/SV_DO.cfm#Concept]. DO is a form of maneuver where small, highly capable units are spread out over a large area of operations. The advantage is created over our enemies through this separation and with coordinated, interdependent, tactical actions. The key is decentralization and distribution of authority where the small unit is the discriminator, decision maker and actor. The challenge is to support the small unit at the same rate and agility that they maneuver, which is especially challenging from the naval ships at sea (sea base).

In response, the DoD has initiated programs to modernize logistics practices and processes. Among them is the requirement to build and deploy Autonomic Logistics (AL). AL is necessary to provide a focused and tailored logistics response to area of operations (AO). It is based upon knowing status, condition and health of all combat equipment in the AO. Embedded sensors monitor levels of consumables (fuel, ammo, water) and condition (health of components, subsystems and systems) and report those through the logistics operational architecture to Global Combat Support Systems (GCSS) and Global Command Control Systems (GCCS). Autonomic logistics fills the critical gap of interpreting, assimilating and synchronizing data from individual platforms into aggregated and actionable calls for supply, support and maintenance. Embedded diagnostics plays a critical role as an enabler for autonomic logistics and is the subject of this article.

The current focus is to determine which technologies and methodologies enable ground vehicle high operational availability during critical short duration high op tempo missions. One of the primary contributors to degraded Ao is loss of functionality and down time from failed vehicle components or line replaceable units (LRU) such as batteries, engines, differentials, etc.. The amount of lost Ao is dependant upon several factors to include: the time it takes to correctly diagnose which LRU failed, the time it takes to remove and replace the failed LRU, and the time it takes to obtain a replacement LRU. In order to increase Ao for ground vehicles, the capability to diagnose critical LRU faults on platform in conjunction with the ability to transmit the request for a replacement LRU and repair assistance to the appropriate logistic and maintenance personnel is needed. The challenges that inhibit this capability are the need for technologies that provide accurate vehicle diagnostic information, the communication network required to move and share data amongst multiple platforms and into higher level enterprise systems in 'real time', and the ability to management this information for a large number of vehicles. The details of how these

PROFILE

Jeffery Banks is an assistant research engineer at Penn State's Applied Research Laboratory. His work in the Systems and Operations Automation division includes the development of asset health monitoring systems for military ground vehicles and the systems engineering of diagnostics and prognostics technology for complex mechanical systems.

Mr. Banks received his M.S. degree in acoustics from The Pennsylvania State University. He received a B.S. degree in mechanical engineering from Villanova University. Prior to ARL Penn State, Mr. Banks worked for Mead Central Research Laboratory as a research engineer in the paper industry. Mr. Banks has extensive experience in machinery diagnostic surveys. Mr. Banks can be reached at (814) 863-3859 or by e-mail at <jcb242@psu.edu>.

challenges are being addressed will be discussed in the following sections.

The capability required to achieve high operational availability is the ability to quickly and accurately diagnose critical LRU faults and failures. This process is most efficiently accomplished through embedded vehicle diagnostic technology. The capability to monitor, detect, and isolate faults to specific LRU's exists for many critical vehicle sub-systems including: diesel engines, drive train components such as the transmission, transfer case, differentials and final reduction drives, and electrical power

Figure 1. Heavy Expanded Mobility Tactical Truck

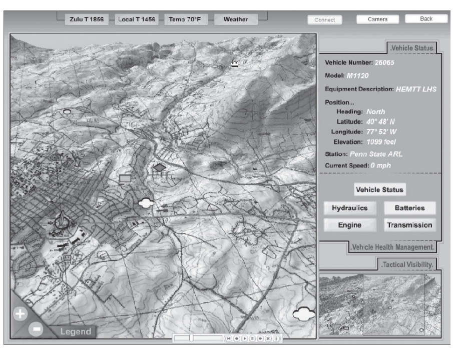


Figure 2. HEMTT Asset Visibility Display

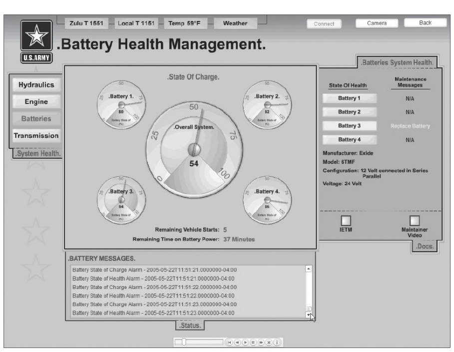


Figure 3. HEMTT Battery Health Display

components such as batteries, motors and generators. An example of embedded diagnostic capability for a DoD vehicle can be demonstrated by the work conducted by Penn State ARL in the development of the vehicle health management system for the U.S. Army Heavy Expanded Mobility Tactical Truck (HEMTT) as shown in figure 1.

This vehicle is a logistic support vehicle designed to operate anywhere in the battle space with a load handling system that is able to self load and unload supplies and materials where they are needed.

The on-board diagnostic system gathers data from various sensors (i.e. pressure, vibration, etc.) located throughout the vehicle sub-systems (i.e. hydraulic, electrical, mechanical) and processes the data using advanced algorithms into vehicle 'health' information. This information is then displayed to the operator and maintainer in a manner that is simple, intuitive and information rich without being too complex. The first information interface display is the Asset Visibility display that is essentially a map with various vehicle represented by icons as shown in figure 2.

This display leverages from existing 'blue force tracking' technology that has been implemented by the U.S. Marine Corps and the U.S. Army. Our intention is not to replicate this technology but show how the health management technology could be integrated into an existing advanced technology that has been previously implemented. The display shows vehicle identification and location information as well as sub-system health status. The sub-system indicators will be grey when no health issues exist, yellow for a health caution indication or red for a health warning indication. The second display is the battery display that shows battery health information for the four vehicle batteries as shown in figure 3.

The battery health page shows diagnostic and prognostic information for the four vehicle batteries. Each of the four smaller gauges on the left side of the display shows state of charge data for each battery. The large gauge shows the system level state of charge for all four batteries because a fault in one battery can adversely affect the entire group of batteries. Below the gauges are two battery prognostic indications including the estimated remaining vehicle starts and the remaining amount of time that the vehicle can run on battery power (i.e. silent watch) and still start the vehicle. The state of health information on the right side of the display will indicate if a fault exists and whether a specific battery should be replaced.

The next display is the hydraulic display that shows hydraulic system diagnostic information for the load handling system as shown in figure 4. The hydraulic gauges on the left of the display show general hydraulic operational parameters including: fluid pressure, reservoir temperature, main control manifold temperature and remaining fluid life (indication of when fluid should be changed). The lights on the right side of the display indicate hydraulic faults for pump failure, oil temperature, reservoir level, sensor failure, lift overload, high pressure filter, return filter, relief valve, low pump pressure, primary, secondary and tertiary hydraulic loop faults, proximity probe 1,2 or 3 faults and a main control manifold fault. These fault indicator lights allow for the diagnosis and localization of a fault to a specific LRU on the vehicle.

The next display is the hydraulic schematic display that shows hydraulic system functional dynamics for the load handling system as shown in figure 5. The schematic display provides a functional overview of the vehicle hydraulic load handling system. This display is dynamic and interactive

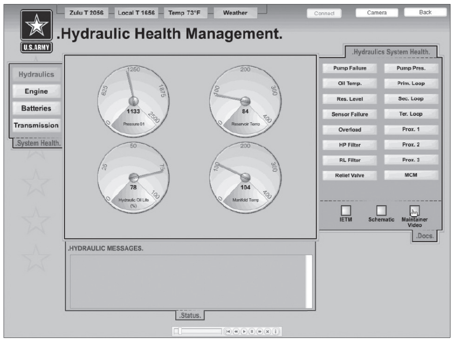


Figure 4. HEMTT LHS Hydraulic System Health Display

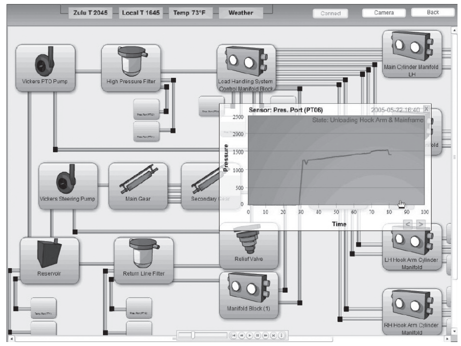


Figure 5. HEMTT LHS Hydraulic System Schematic Display

Figure 6. HEMTT Vehicle Health Display

and it displays not only all of the components (i.e. pumps, manifolds, ram cylinders, etc,) of the hydraulic system but it also shows the dynamic fluid flow between the components during LHS operation. This display allows for the user to look at the raw data from any of the pressure, temperature or levels sensors from the previous load or unload cycles. This facilitates a better understanding of how the system functions and also allows for manual interrogation and troubleshooting of the hydraulics by a system level expert. This display would be very useful to the OEM as a field service tool and also at the school house for training on the operation and maintenance of the system.

The final display is the vehicle status display that shows the location of faults for the hydraulic, battery, engine and transmission sub-systems as shown in figure 6. The vehicle display provides a simple and graphic display for showing the location of LRU faults. This provides the capability for the maintainer to quickly apply maintenance to the correct component, where maintenance is needed. This display is also dynamic in that the vehicle can be rotated to different views that best shows a specific component. The fault component can also been shown with an animated zoom view to show the details of the component. A movie demonstration of the vehicle health management system can be viewed from the ARL website at http://soademo.arl.psu.edu/hemtt/.

Another capability required to achieve high operational availability is the ability to obtain and process information that is needed by the support and supply organizations to provide the logistical materials to the operations and maintenance organizations, which enables them complete their functions efficiently and effectively. This concept is known as autonomic logistics and a graphical example of the implementation of autonomic logistics is shown in figure 7.

This AL scenario for a typical Marine Corps mission involves forward deployed combat vehicles such as the light armored vehicle (LAV) and the amphibious assault vehicle (AAV) with logistic support being provided by the medium tactical vehicle replacement (MTVR). These vehicles can utilize GPS technology to determine their location in real time and they can transmit their platform identification and location as well as their vehicle health, fuel level, ammunition level and mobile load back to Global Combat System Support–Marine Corps (GCSS-MC) and Global Command and Control System-Marine Corps (GCCS-MC). These organizations can compile and process this information using computer networks designed to analyze large amounts of data from multiple sources. The focus is to determine, ‘what is the most effective and efficient strategy for meeting all of the logistics needs of all of the assets in the battle space when taking into consideration the mission objectives and the ever changing operational challenges that arise during combat?’ With all of this information being feed through the information network autonomously, the Marine Corps can coordinate transporting the correct and necessary logistic materials from the seabase to the individual ground vehicles and elements that each have specific logistic needs.

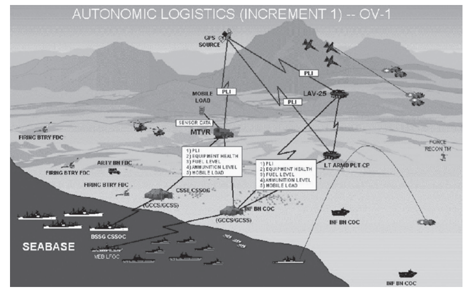


Figure 7. Example of Implementation of Autonomic Logistics

Penn State ARL is currently working on solutions for increasing military ground vehicle operational availability with the development of advanced embedded vehicle diagnostic technology and net-centric based autonomic logistic capability. Through the prototype implementation of these technologies and capabilities we can demonstrate the ‘vision’ of data and information exchange between multiple networks and platforms for the efficient and effective management of ground vehicle assets anywhere that their mission objectives takes them.

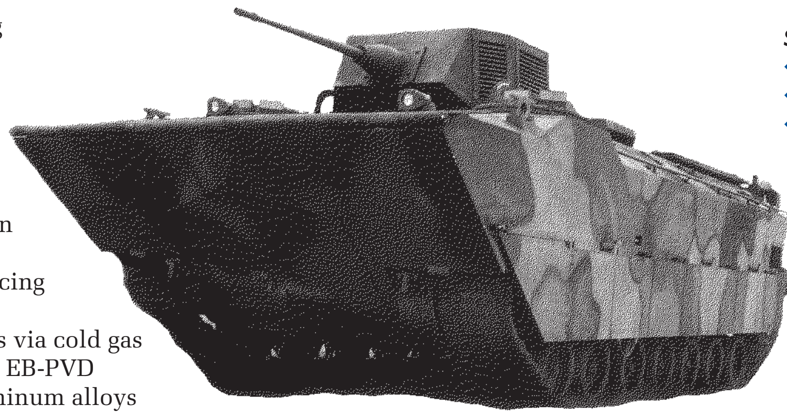
ARL Penn State Ground Combat and Combat Service Support Vehicle Technology Group

It is appropriate to note in this issue ARL Penn State's efforts in vehicle technology. Complimenting this effort is Penn State's Pennsylvania Transportation Institute <www.pti.psu.edu>, which provides test bed capabilities for various research efforts. The integration of advanced materials, manufacturing processes, tooling, and fixturing are strengths within iMAST resources. These efforts can result in reductions in gross weight, vibration, interior noise, and life-cycle costs as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant deductions in labor and in operating and support (O&S) costs.

Health Usage Monitoring System Technologies
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnosis

Track Vehicle System Technologies
- Lightweight HS materials
- Laser cladding and heat treating

CBR Technologies
- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents



Signature Reduction Technologies
- Composite thermal tiles
- Radar cross-section reduction
- Acoustics

Powertrain Technologies
- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB-PVD
- Spray formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

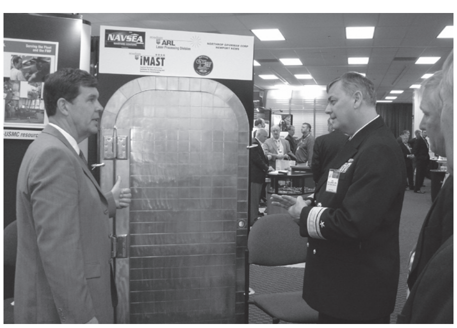
Repair Technology
- NDI technologies (shearography)
- Coating application and removal
- Component repair methods (laser cladding)

Drive System Technologies
- Advanced gear and bearing steels
- Laser fabricated (cut and welded) housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Structural System Technologies
- Armor systems
- Materials and design

Other
- Conceptual design trade studies
- Manufacturing process modeling

INSTITUTE NOTES



iMAST director Bob Cook shows RAdm William Landay, Chief of Naval Research, a watertight ship enclosure effort being produced in support of the Navy ManTech program effort at ARL Penn State.

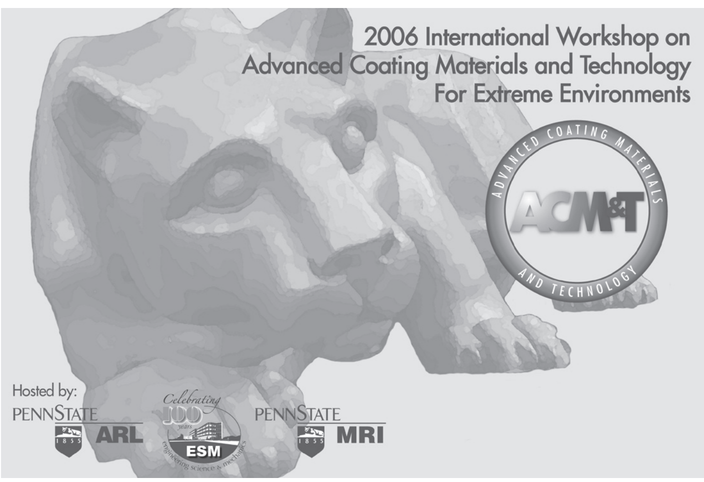
Navy League Expo

The annual Navy League Sea-Air-Space Exposition held in Washington, D.C. once again provided an opportunity for iMAST to share program information with Navy and industry leaders. Significant industry participation drew large numbers of Navy and Marine Corps officials, as well as the U.S. Coast Guard. This year's theme "Operations from the Maritime Domain" discussed current operational issues which focus on speed, agility, flexibility and sustainment against an asymmetric foe. The issue of human capital, namely our Sailors, Marines, Coastguardsmen and merchant mariners was also foremost in the presentations. The partnership between industry and the Sea Services provides a cooperative environment where the very best technologies and equipment can be developed and are made available to the sea service warriors who carry out those missions at the tip of the spear. Founded with encouragement by President Roosevelt in 1902, the Navy League of the United States is a civilian organization dedicated to informing the American public and government that the United States is a maritime nation, and that its national defense and economic well-being are dependent upon a strong sea service. ARL Penn State is proud to be a corporate member of the Navy League.

iMAST's Tom Hite (center) discusses iMAST programs with Ron Muffie and Jim Rea from Mountain Research Inc.

SBIR/STTR Workshop Conducted

iMAST recently helped Penn State University's Industrial Research Office host a Navy Small Business Innovation Research/ Small Business Technology Transfer (SBIR/STTR) workshop presentation in State College, PA. Mr. John Williams, Director of the Navy's SBIR/STTR program, provided an overview on the program, further addressing its benefits to the numerous attendees. The workshop further provided an opportunity for iMAST to network with various organizations and companies relative to Navy Manufacturing Technology program effort. The workshop included presentations on solicitation schedules, as well as proposal writing. The Department of Defense SBIR/STTR programs fund over a billion dollars in early-stage R&D projects at small technology companies each year. These projects serve a DoD need and also have commercial applications. The SBIR program can provide up to $850,000 in early-stage R&D funding directly to small technology companies. The STTR program also provides up to $850,000 in early-stage funding directly to companies working cooperatively with researcher at universities and other research institutions. iMAST and ARL Penn State continues to support the Navy's SBIR/STTR program. For more information about the Navy's SBIR contact John Williams at (703) 696-0342, or by e-mail at <williajr@onr.navy.mil>.



September 12-13, 2006
The Penn Stater Conference Center Hotel
215 Innovation Boulevard, State College, PA 16803

2006 International Workshop on Advanced Coating Materials and Technology for Extreme Environments

You are cordially invited to attend this dynamic workshop which will provide a forum for exchanging information among leading researchers in the area of new coating materials and technologes needed for power and propulsion systems (e.g. fuel cells, engines, etc.) and related applications. This workshop will address current and future challenges enabling extended life of critical parts and components under extreme environmental conditions. This includes oxidation, corrosion, wear and erosion. Primary materials to be addressed include metallic, ceramic and composites. This workshop will link field experience, coating requirements, and technologies with various members of the materials community. Selected topic research papers and round table discussions are planned. Poster presentations are welcome from government, industry and academia. Plan to discuss state-of-the-art coating technologies that will provide potential road maps for meeting future needs.

- Corrosion and Oxidation Resistant Materials
- Thermal Protection Systems including TBC, EBC
- Erosion and Wear Resistant Materials
- Smart Coatings and Health Monitoring

For full workshop details, call for papers, or to register online, visit: http://www.arl.psu.edu/advcoat.htm

CALENDAR OF EVENTS

2006

9–11 May	American Helicopter Society Forum 62	★★★★★★★ *visit the iMAST booth*	Phoenix, AZ
1–2 Jun.	Johnstown Showcase for Commerce	★★★★★★★ *visit the iMAST booth*	Johnstown, PA
5–7 Jun.	Navy Opportunity Forum		Washington, D.C.
12–15 Jun.	Mega Rust 2006 Marine Coatings & Corrosion Conference		Norfolk, VA
13–14 Jun.	M2AB Meeting: Ground Combat/Combat Service Support Vehicles		State College, PA
27–28 Jun.	U.S. Coast Guard Innovation Expo		Tampa, FL
31 Jul.–3 Aug.	ONR Naval S&T Partnership Conference	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
16–18 Aug.	ARMTech Showcase for Commerce	★★★★★★★ *visit the iMAST booth*	Kittanning, PA
21–25 Aug.	Penn State Rotary Wing Technology Short Course		State College, PA
12–13 Sep.	ARL Penn State International Workshop on Advanced Coatings Technologies		State College, PA
12–14 Sep.	Marine Corps League Expo	★★★★★★★ *visit the iMAST booth*	Quantico, VA
9–11 Oct.	AUSA Expo		Washington, D.C.
16 Oct.	Penn State Center for Space Research Programs Workshop "State of Space Business"		University Park, PA
23–26 Oct.	Expeditionary Warfare Conference		Panama City, FL
Oct. TBA	DoD Maintenance Conference		TBA
27–30 Nov.	DMC 2006	★★★★★★★ *visit the iMAST booth*	Nashville, TN

2007

3–5 April	Navy League Sea-Air-Space Expo	★★★★★★★ *visit the iMAST booth*	Washington, D.C.
1–3 May	American Helicopter Society Forum 63	★★★★★★★ *visit the iMAST booth*	Virginia Beach, VA

Quotable

"I have not failed. I've just found 10,000 ways that won't work."
—Thomas Edison

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